



9th International Conference on Air Quality – Science and Application

Evaluation of air quality impacts with an integrated assessment model for Spain

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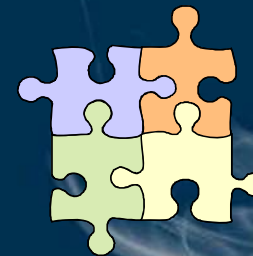
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Outline



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- 1. Introduction.**
- 2. Model testing and evaluation.**
- 3. Conclusions.**
- 4. Next steps.**
- 5. References.**



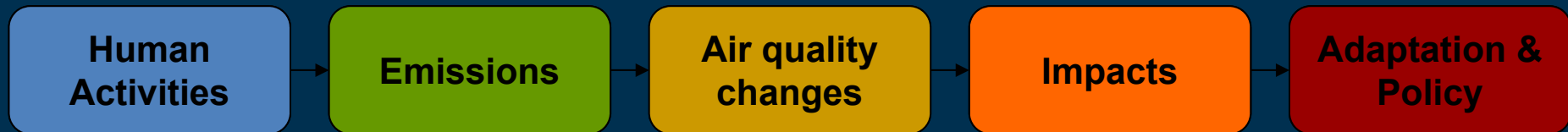


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Introduction

Integrated Assessment Modeling



Cause



Effect

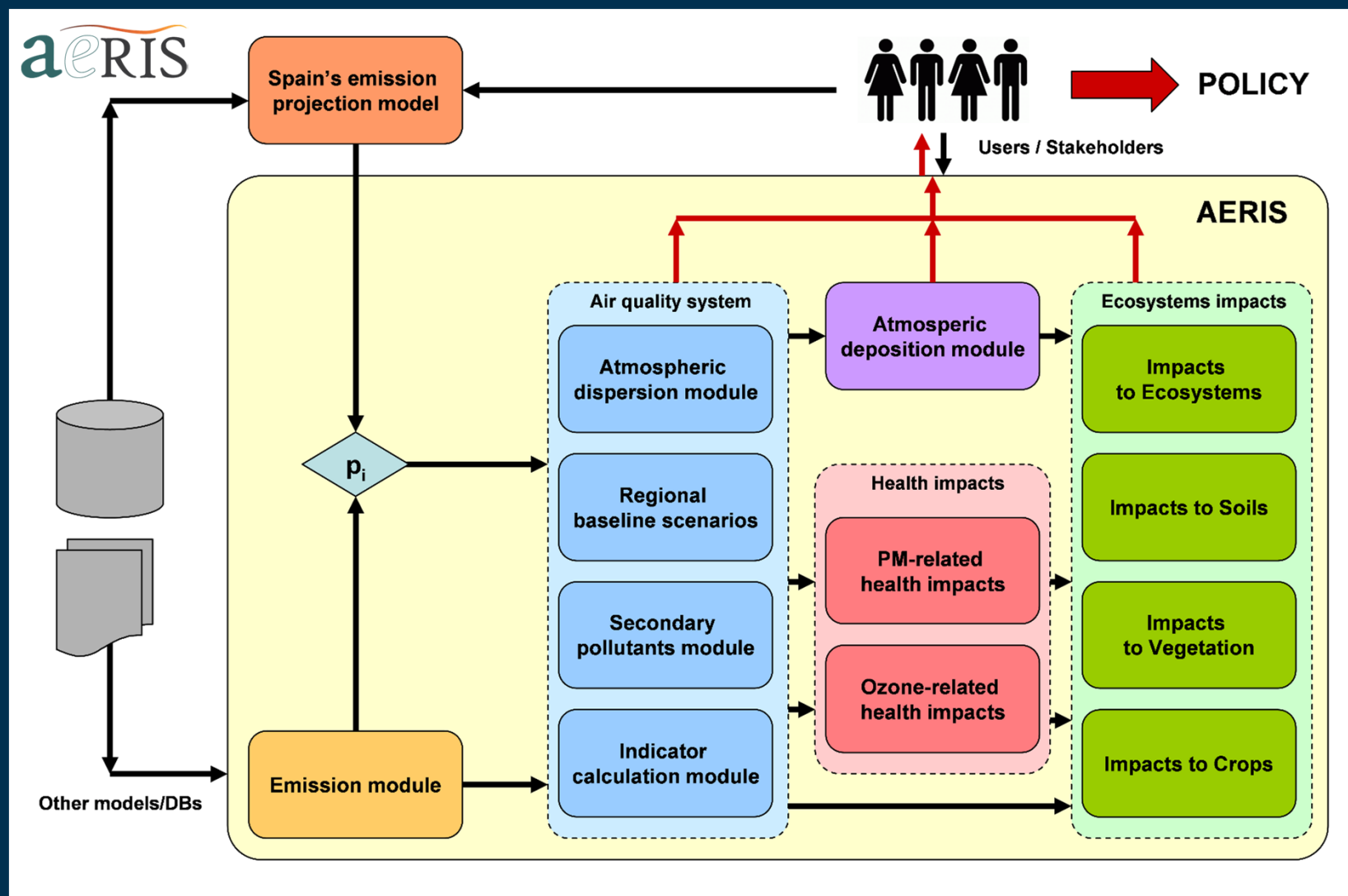
- Provides a **holistic** description of environmental problems under a **policy-driven** framework.
- Methodology for gaining **insight** about the complex **interactions** between phenomena.
- Intended to **satisfy** the needs of a wide range of **stakeholders**. Quick response. No intensive computations involved.
- Broader scope – description of phenomena is **simplified**.

The AERIS model



- **AERIS** – **A**tmospheric **E**valuation and **R**esearch **I**ntegrated system for **S**pain.
- **Multi – pollutant** approach: SO_2 , NO_2 , NH_3 , PM_{10} , $\text{PM}_{2.5}$. Describes formation of O_3 and secondary particles. **Deposition** of nitrogen (N_{dep}) and sulphur (S_{dep}) species.
- **Addresses air quality variations** and impacts as a function of **percentual variations in emissions** against a **reference scenario**:
 - Impacts on forests and crops (O_3 , SO_2).
 - Impacts on human health ($\text{PM}_{2.5}$, O_3).
 - Impacts on ecosystems and soils (N_{dep} , S_{dep}) – **under development**.
- Basic methodology described in **Vedrenne et al., (2014)** – ***Environmental Modelling & Software*** – (in press).

Structure of AERIS



Impacts on forests and crops



Impacts are quantified in terms of:

- Critical levels of SO_2 and NO_2 for **forests**.
- Relative **yield losses** caused by O_3 to 9 **crop species**.

Forests – broadleaved deciduous, broadleaved evergreen, mixed leaf, needle-leaved evergreen and flooded forests.

Crops – grape, maize, potato, rice, sunflower, tobacco, tomato, watermelon and wheat.

Concentration levels for the before mentioned pollutants are crossed with relevant spatial information (i.e. CORINE Land Cover 2000, FAO) and **impact quantification models** (Ashmore et al., 2004; Mills et al., 2007).

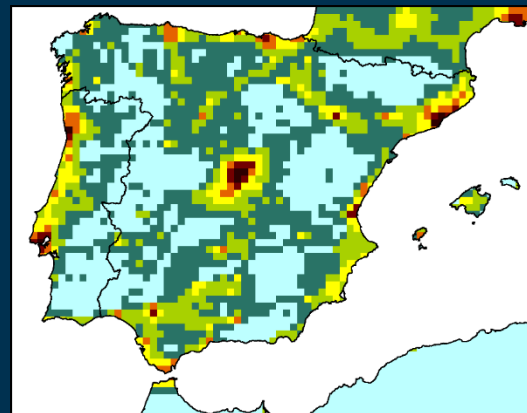
Impacts on forests and crops



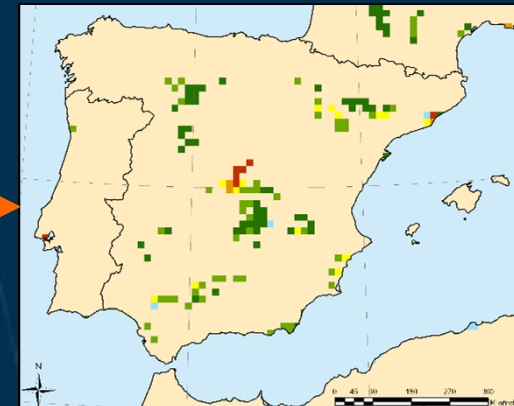
NO₂ critical level exceedances for forests.



CLC 2000 Forests



$$Ex_{Cl} = \max\{C_i - Cl_i, 0\}$$



Ex_{Cl,NO2}

NO₂ Mean Annual Concentration (e.g. 2007)

Impacts on health



Derived from exposure. Impacts are quantified in terms of:

- Change in the statistical **life expectancy** (months).
- Total number of **life years lost** (YOLL).

Methodological framework adapted from **IIASA (Mechler et al., 2002)** and **WHO (Murray et al. 2002)**. Based on the survival function and population counts for Spain, Portugal, Andorra, France, Morocco and Algeria.

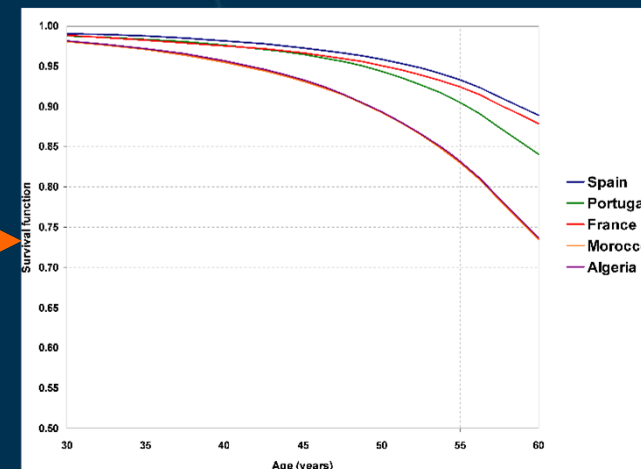
Life tables
(UN, WHO)



$$l_c(t) = \exp \left(- \sum_{z=c}^t \mu_{z, z-c+s} \right)$$



Survival functions

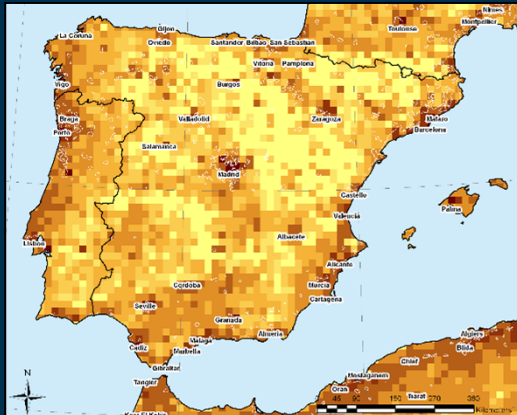


Impacts on health

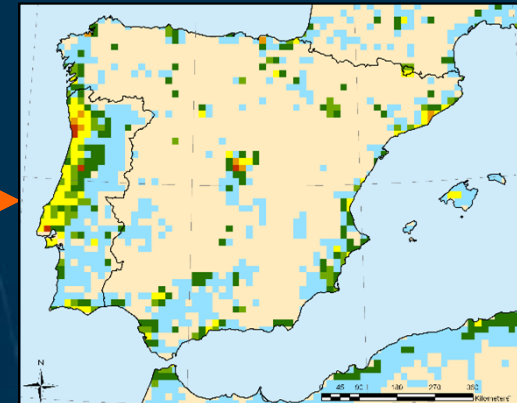


YOLL due to exposure to $PM_{2.5}$

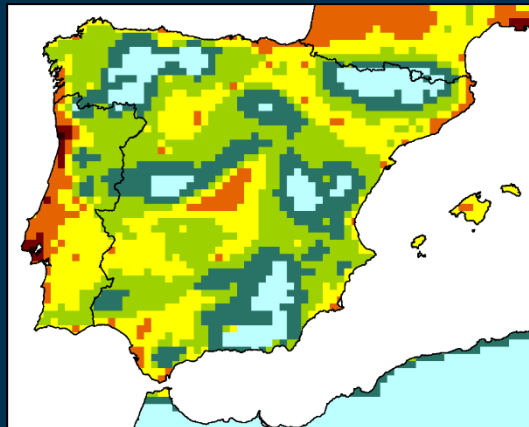
Population counts



$$YOLL = \beta \cdot PM \cdot Pop_j \cdot f_c \cdot \int_c^{w_1} l_c(t) \cdot \log l_c \cdot dt$$



YOLL- PM_{25}



$PM_{2.5}$ Mean Annual Concentration (e.g. 2007)

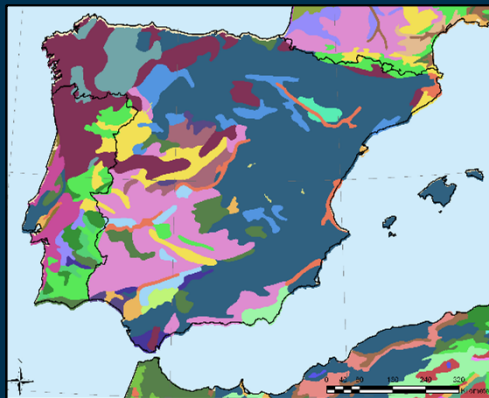
Impacts on ecosystems/soils



Estimated as an exceedance of a **critical load**.

- Absolute exceedance of critical loads for **soils**.
- Under development. Currently quantified: $CL_{nut}(N)$, $CL_{min}(S)$, $CL_{max}(S)$.

The general approach is outlined by the Coordination Centre for Effects (CCE) (Posch et al., 2001; Reinds et al., 2008). Quantified for soils with the VSD model provided by CCE.

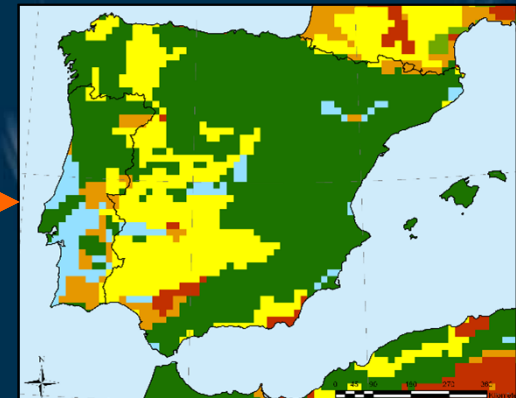


Soil types and properties

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VSD model



$CL_{max}(S)$



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Model testing and validation

Model testing



The impacts estimated by **AERIS** will be **compared** to the outputs produced by reference models: **SERCA** and **GAINS**. Emissions will be the same in both cases.

Comparison with SERCA → Relative yield loss of wheat (*triticum aestivum*) produced by exposure to O_3 .

Comparison with GAINS → Change in the statistical life expectancy due to exposure to $PM_{2.5}$ in cohorts of >30 years old.

Testing will involve conducting a **concurrent comparison** based in **statistical performance** (Pearson correlation coefficients, mean scores and scatterplots).

Comparison with SERCA



SERCA (**Sistema de Evaluación de Riesgos de la Contaminación Atmosférica**) estimates damage to crops and forests due to exposure to O_3 (**de Andrés et al., 2012**).

- **Emission scenario: 2014 National Emission Scenario.** Quantified with the SEP model (projections).
- **Emission sectors** and activities in SERCA and AERIS are **identical** → SNAP sectors (no adaptation needed).
- **Spatial resolution** in SERCA and AERIS for the **Iberian domain** are the **same** (16 km × 16 km).
- **Comparison based on a statistical analysis.**

Comparison with SERCA



2014 National Emission Scenario (SERCA & AERIS)

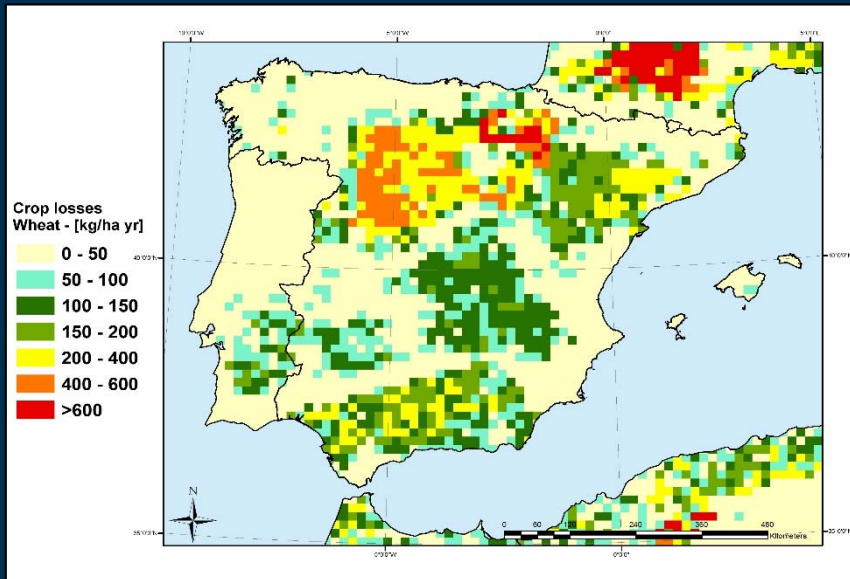
SNAP code	Activity name	NO_x	SO_2	PM_{10}	$PM_{2.5}$	NH_3
010000	Coal - fired power plants $\geq 300MW$	-58.80	-88.22	0	0	0
020202	Residential plants $< 50MW$ 15.56	-59.75	-5.74	-5.33	0	
030000	Combustion in manufacturing	-58.85	-33.05	0	0	0
040000	Production processes	0	-7.30	0	0	0
070101	Passenger cars - highway driving	-62.11	0	-48.16	-48.16	0
070103	Passenger cars - urban driving	-17.35	0	-67.53	-67.53	0
070201	Light - duty vehicles - highway driving	-47.70	0	-68.37	-68.37	0
070203	Light - duty vehicles - urban driving	-83.20	0	-90.11	-90.11	0
070301	Heavy - duty vehicles - highway driving	-3.93	0	-69.11	-69.11	0
070303	Heavy - duty vehicles - urban driving	-65.04	0	-88.61	-88.61	0
0707/08	Break, tire and road abrasion	0	0	-17.52	-16.75	0
080500	Airports (air traffic)	-27.52	0	0	0	0
080600	Agriculture (machinery)	-41.39	-51.54	-90.41	-90.41	8.73
080800	Industry (machinery)	-20.05	103.89	-42.33	-42.33	3.48
100101	Culture w/ fertilizers - permanent crops	0	0	0	0	-20.41
100102	Culture w/ fertilizers - arable land crops	0	0	0	0.00	-11.15
100500	Other agricultural activities	0	0	22.63	38.71	-7.33
110000	Other sources and sinks	0	0	0	0	-12.31
—	Portugal	-20.11	-21.01	13.11	-3.81	42.11
—	Total (t/yr)	947735	427555	121644.8	75850	397518
—	%_{Total} (2007)	-39.5%	-64.7%	-35.7%	-48.0%	-12.1 %

^a Presented as variation percentages with respect to the 2007 National Emission Scenario

Comparison with SERCA

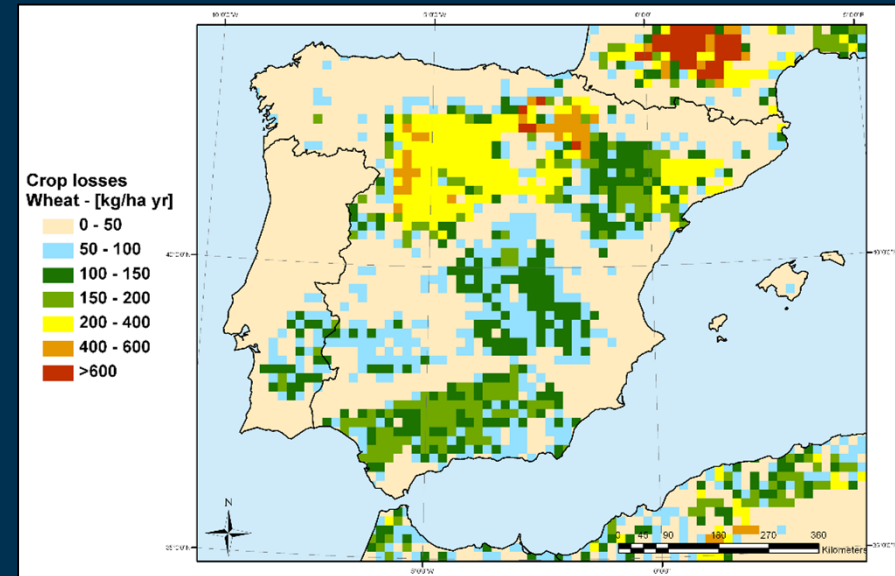


Results (yield losses)



SERCA

$$X_{\text{SERCA}} = 66 \text{ kg/ha yr}$$



AERIS

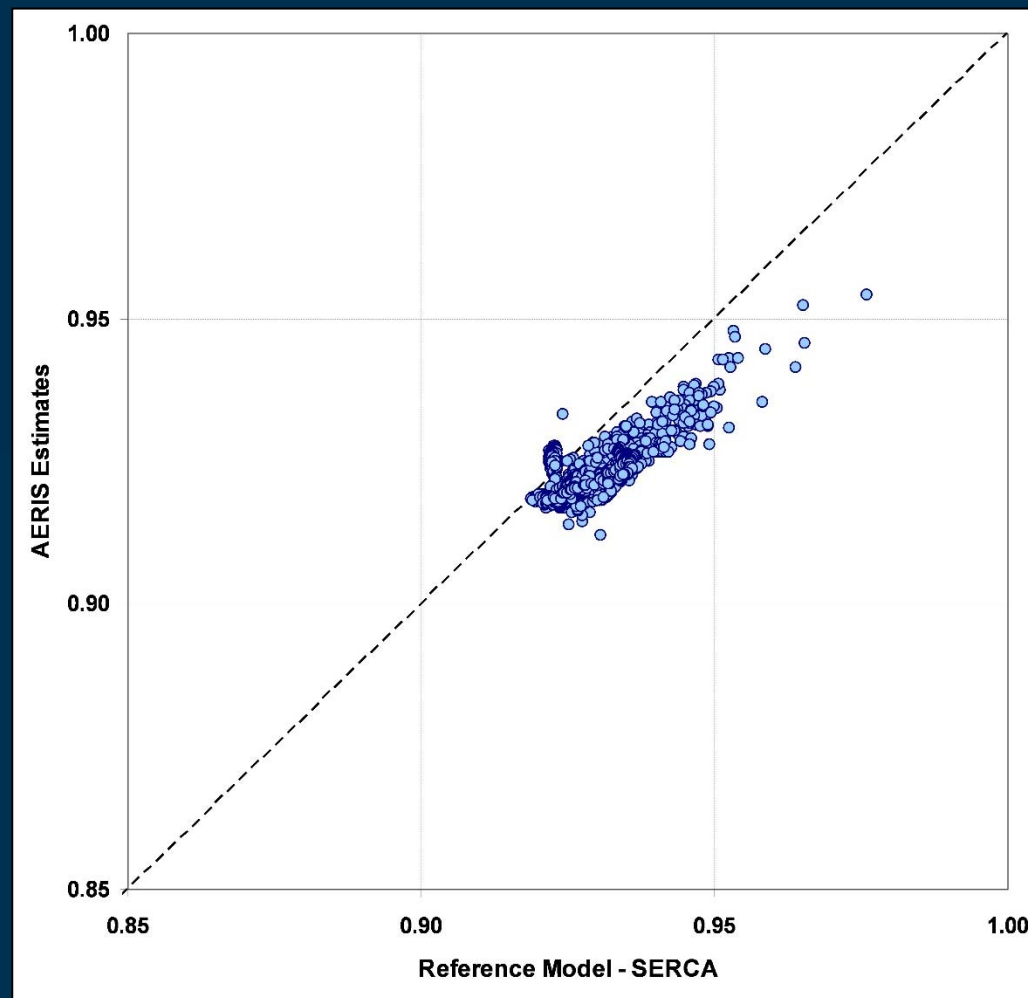
$$X_{\text{AERIS}} = 64 \text{ kg/ha yr}$$

*Results presented as annual crop outputs.

Comparison with SERCA



Results



$$r = 0.8392$$

***Results presented as relative yield fractions.**

Comparison with GAINS



GAINS is able to estimate health impacts caused by exposure to $PM_{2.5}$, according to the methodology published in **Mechler et al., (2002)** and **Amann et al., (2011)**.

- Emission scenario: **Gothenburg Protocol Revision** (National Projections 2020).
- Referring GAINS emissions (**aggregated** by activity and **sector**) to SNAP groups considered by AERIS.
- Adapt the results of AERIS (16×16 km) to the **minimum spatial resolution**. In this case, to the scale of GAINS (50×50 km).
- Comparison based on a **statistical analysis**.

Comparison with GAINS



Gothenburg Protocol Revision - GAINS

GAINS	Activity name	NO _x	SO ₂	PM ₁₀	PM _{2.5}	NH ₃
PP_ECL	Power & district heat plants, exsting; coal	38.38	22.86	0	0	0
GR	Residential, commercial, services, agriculture, etc.	38.13	15.34	2.71	2.21	0
IB_BO_COB	Industry: transformation sector, combustion in boilers	4.45	5.02	0	0	0
IB_BO_OTB	Industry: combustion of fossil fuels other than coal	19.52	8.91	0	0	0
IB_BO_OTB_L	Industry: combustion of coal in large boilers	0.06	0.11	0	0	0
IB_BO_OTB_S	Industry: combustion of coal in small boilers	0.01	0.03	0	0	0
IB_BO_PAP	Industry: paper and pulp production	9.32	7.82	0	0	0
IB_BO_CHEM	Industry: chemical industry	3.51	0	0	0	0
IB_OC	Industry: Other combustion (used in emission tables)	56.56	12.88	0	0	0
PR_COB	Ind. Process: Cement production	0	37.93	0	0	0
PR_LIME	Ind. Process: Lime production	0	5.17	0	0	0
PR_COKE	Ind. Process: Coke oven	0	1.92	0	0	0
PR_GLASS	Ind. Process: Glass production (flat, blown, container glass)	0	3.57	0	0	0
PR_OT_NFMS	Ind. Process: Other non-ferrous metals prod.	0	36.05	0	0	0
PR_PULP	Ind. Process: Paper pulp mills	0	19.22	0	0	0
PR_OSP	Ind. Process: Crude oil & other products	0	43.77	0	0	0
PR_SINTER	Ind. Process: Agglomeration plant - sinter	0	6.15	0	0	0
PR_SULF	Ind. Process: Sulfuric acid	0	13.23	0	0	0
TRA_BO_LDLC	Light duty vehicles: cars and small buses	91.02	0	3.04	3.04	0
TRA_BO_LDCT	Light duty vehicles: light commercial trucks	30.17	0	1.17	1.17	0
TRA_BO_HCB	Heavy duty vehicles - buses	12.39	0	0.17	0.17	0
TRA_BO_HCT	Heavy duty vehicles - trucks	76.46	0	0.81	0.81	0
TRA_BO_NCB	Non-exhaust PM emissions	0	0	11.40	4.69	0
TRA_OT_AIR	Other transport: air traffic - civil aviation	13.76	0	0	0	0
TRA_OT_AGR	Other transport: agriculture and forestry	42.25	0.05	3.15	2.98	0
TRA_OT_CON	Other transport: construction and industry	17.76	0.03	1.05	0.99	0
FCOBI_OTHN	Fertilizer use - other N fertilizers	0	0	0	0	37.54
FCOBI_UREA	Fertilizer use - urea	0	0	0	0	40.44
AGR_ARABLE	Agriculture: Ploughing, tilling, harvesting	0	0	8.06	1.79	0
AGR_OSP	Agriculture: Livestock - other cattle	0	0	1.26	0.28	27.22
AGR_OSD	Agriculture: Livestock - dairy cattle	0	0	0.23	0.05	19.18
AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	0	0	0	0	32.79
AGR_PIG	Agriculture: Livestock - pigs	0	0	12.41	2.21	101.9
AGR_POULY	Agriculture: Livestock - poultry	0	0	10.77	2.39	32.35
CSMR_3000_NLKR	Milk yield over 3000 kg/animal threshold	0	0	0	0	9.14
PORTUGAL	Portugal	115.7	67.26	91.15	62.35	69.62

^a Emissions are presented in annual metric tons (t • yr⁻¹)

Comparison with GAINS



Gothenburg Protocol Revision - AERIS

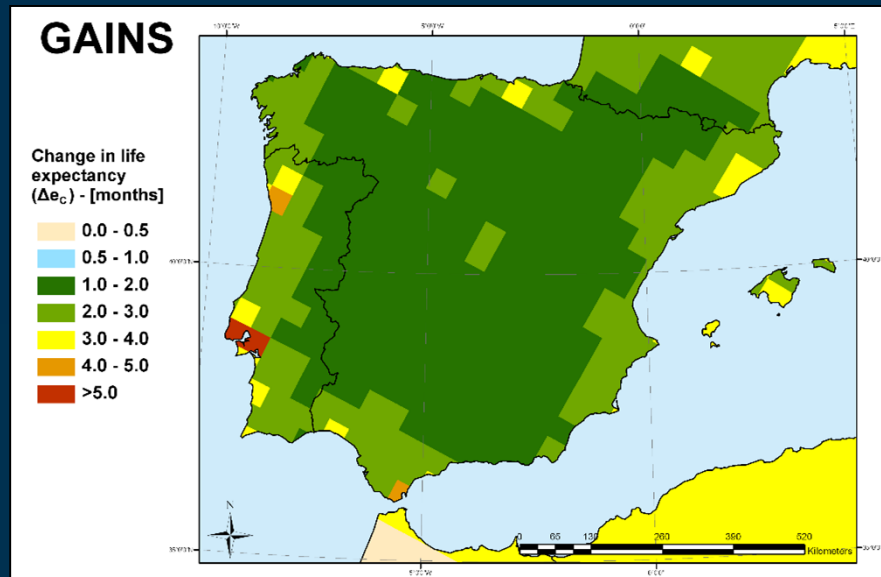
SNAP code	Activity name	NO_x	SO_2	PM_{10}	$PM_{2.5}$	NH_3
010000	Coal - fired power plants $\geq 300MW$	-81.2	-96.9	0	0	0
020202	Residential plants $< 50MW$	98.4	23.4	-84.7	-85.6	0
030000	Combustion in manufacturing	-66.0	-69.3	0	0	0
040000	Production processes	0	-50.4	0	0	0
070101	Passenger cars - highway driving	-52.2	0	-75.3	-75.3	0
070103	Passenger cars - urban driving	-52.2	0	-75.3	-75.3	0
070201	Light - duty vehicles - highway driving	-49.1	0	-76.2	-76.2	0
070203	Light - duty vehicles - urban driving	-49.0	0	-76.2	-76.2	0
070301	Heavy - duty vehicles - highway driving	-43.6	0	-95.1	-95.1	0
070303	Heavy - duty vehicles - urban driving	-43.6	0	-71.2	-71.2	0
0707/08	Break, tire and road abrasion	0	0	-1.1	-26.0	0
080500	Airports (air traffic)	70.7	0	0	0	0
080600	Agriculture (machinery)	-65.7	-99.5	-96.7	-96.9	0
080800	Industry (machinery)	-75.3	-82.3	-93.1	-93.5	0
100101	Culture w/ fertilizers - permanent crops	0	0	0	0	-38.5
100102	Culture w/ fertilizers - arable land crops	0	0	0	0	-38.5
100500	Other agricultural activities	0	0	97.8	138.1	84.5
110000	Other sources and sinks	0	0	0	0	-92.9
—	Portugal	-20.2	-21.0	13.1	-3.8	42.1
—	Total (t/yr)	1288962	747660	135323	94559	377361
—	%_{Total} (2007)	-17.7%	-38.3%	-25.7%	-25.3%	-19.8%

^a Presented as variation percentages with respect to the 2007 National Emission Scenario

Comparison with GAINS

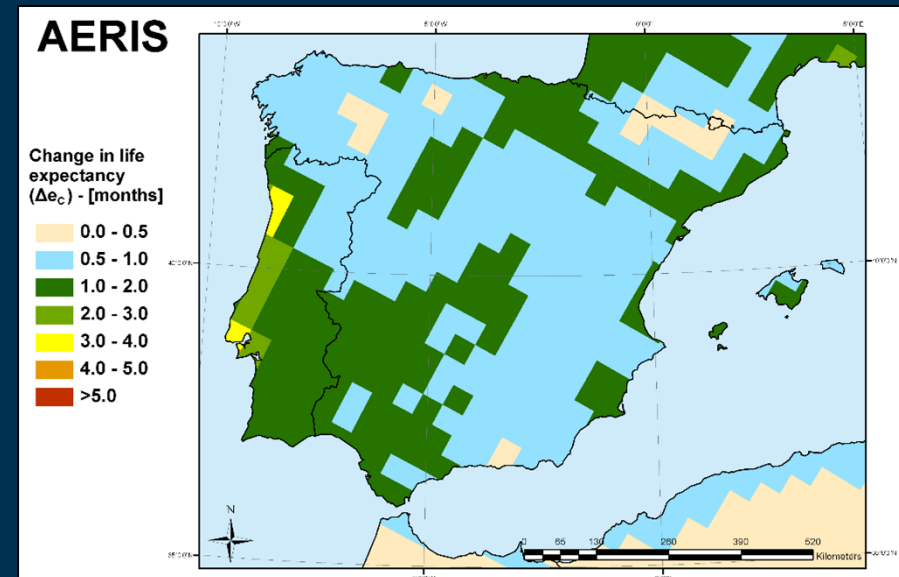


Results (change in life expectancy)



GAINS

$$x_{\text{SERCA}} = 2.03 \text{ months}$$



AERIS

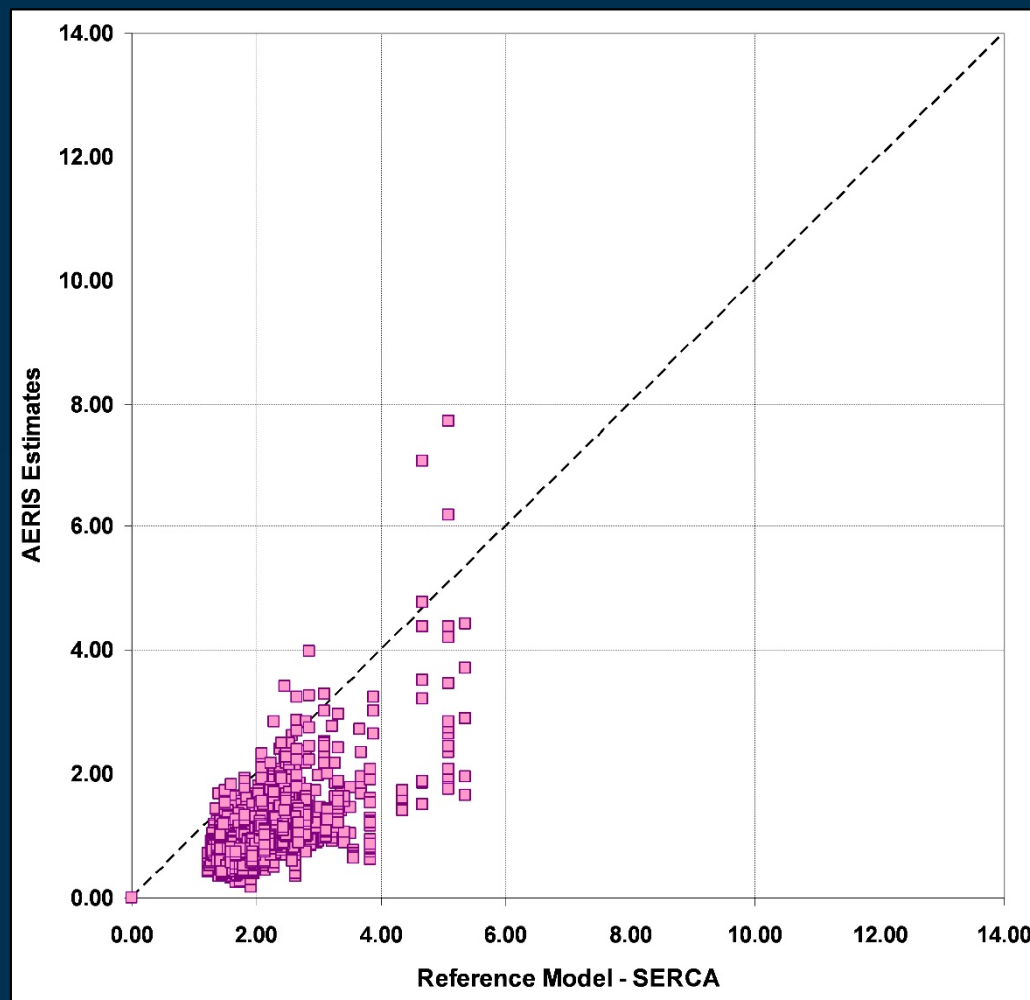
$$x_{\text{AERIS}} = 1.06 \text{ months}$$

*Results presented as months of life expectancy losses.

Comparison with GAINS



Results



$$r = 0.7204$$

*Results presented as months of life expectancy losses.



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Conclusions & Next Steps

Conclusions



- Adequate correlations were observed for both comparisons. Similar **order of magnitude** between outputs.
- Conducting a **classical benchmarking** exercise – **limited** for GAINS. IAMs developed with **different air quality models**. Impacts quantified with **different data**.
- Analysing the **similarities** between model outputs increases the perception of a “**fitness-for-purpose**” IAM among stakeholders.
- The **comparison** with **reference** models provides interesting starting points for **legitimizing** the use of **AERIS** and have **confidence** in its results.

Next steps



- **Full version** available in late **2014**. Results on the remaining modules will be introduced shortly (i.e. critical loads, ecosystems, etc.).
- Include an **extension** for the quantification of **cost-effective** results (abatement costs and optimization modules).
- The **evaluation** of models should be a **central part** of the model development process, not an **afterthought**. Therefore it should be refined in the future.
- **Circulate** AERIS among **stakeholders** and policy developers for feedback. Increasing model **legitimacy** and **reliability** perception.
- **Possibly reduce scale** and create a version for **Madrid**.

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END

Thank you for your attention!